SYLLABI
OF
PG / Ph. D. COURSES
(DEPARTMENT OF PHYSICS)

(Revised and Approved by the 24th Academic Council Meeting, held on 6th May, 2017)

NORTH EASTERN REGIONAL INSTITUTE OF SCIENCE & TECHNOLOGY
(UNDER THE MINISTRY OF EDUCATION, GOVT. OF INDIA)
DEEMED TO BE UNIVERSITY U/S 3 OF THE UGC ACT, 1956
NIRJULI - 791 109 :: ARUNACHAL PRADESH

Ph.D. Physics
COURSE STRUCTURE

S. No.	COURSE CODE	COURSE TITLE	L	T	P	Cr
1	PH9001	Research Methodology in Physics	3	0	0	3
2	PH9002	Lasers, Instrumentation and Applications	3	0	0	3
3	PH9003	Group Theory, Spectroscopy and Diffraction Method	3	0	0	3
4	PH9004	Luminescent Materials and Their Applications	3	0	0	3
5	PH9005	Lie Algebraic Techniques in Physics	3	0	0	3
6	PH9006	Climate Physics	3	0	0	3
7	PH9007	Plasma Physics	3	0	0	3
8	PH9008	Modern Applications of Spectroscopy	3	0	0	3
9	PH9009	Microwave Electronics and Antenna Theory	3	0	0	3

Note: Total credits earned for the Ph.D. course work will be as per academic bye laws. Research Methodology is a compulsory course for Ph. D. course work.

PH9001 : Research Methodology in Physics

(Pre-PhD course work compulsory paper) **3 0 0 3**

UNIT-I	**Definition of the problem:** identifying and formulating the problem, techniques involved in solving problem: (a) exact analytical solutions of equations involved, (b) numerically solving equations, (c) simulating the problem on a computer, Monte Carlo or molecular dynamics approach, (d) experimental observations and theoretical modeling.	10 lectures
UNIT-II	**Research design and ethics**: review of research literature, purpose and use of literature review, locating relevant information, uses of library and electronic databases, identification of gaps in reasearch, formulation of research problem, definition of research objective, preparation and presentation of literature review, theoretical models and frame work, scientific ethics, copyrights and plagiarism.	10 lectures
UNIT-III	**Analyzing data:** errors and analysis of errors, introductory probability and stochastic processes, descriptive statistics and correlations.	8 lectures
UNIT-IV	**Using computers in research:** Handling different operating systems, (a)literature survey using web, handling search engines, (b) computer usage for collecting/analyzing data, simulations using Fortran/ C++/Mathematica/Matlab/Molden, (c) preparation of research articles, thesis and presentation, research papers: using word processing software-MS Word/Latex/others, drawing graphs and diagrams-Origin/Statistica/Excel/others, seminar presentations-Power point or oral and poster presentations.	14 lectures

Recommended Books:

1. How to Write and Publish, R. A. Day and B. Gastel (Cambridge University Press)
2. Probability and Statistics for Engineers and Scientists, S. Ross (Academic Press)
3. Research Methodology: Methods and Techniques, C. R. Kothari (Vishwa Prakashan)
4. Data Reduction and Error Analysis for Physical Sciences, P.R. Bevington and D.K. Robinson (http://www.physast.uga.edu/files/phys3330_fertig/BasicErrorAnalysis.pdf)

PH9002 : Lasers, Instrumentation and Applications

(Pre-PhD course work optional paper) **3 0 0 3**

UNIT-I	**Different lasers: Principle** and working of CO2 laser and qualitative description of longitudinal and TE laser systems, threshold condition for oscillation in semiconductor laser, semiconductor lasers, diode laser, p-n-junction laser, GaAs laser, Nd-YAG lasers, principle and working of dye laser, free electron laser.	8 lectures
UNIT-II	**Nonlinear processes:** wave propagation in an anisotropic crystal, polarization response of materials to light, harmonic generation, second harmonic generation, sum and difference frequency generation, phase matching, third harmonic generation, bistability, self focusing, fiber lasers, stimulated Raman scattering, CARS.	8 lectures
UNIT-III	**Novel applications of laser:** cooling and trapping of atoms, principles of Doppler and polarization gradient cooling, qualitative description of ion traps, optical traps and magneto-optical traps, evaporative cooling and Bose-Einstein condensation.	8 lectures
UNIT-IV	**Detectors and spectroscopic techniques:** grating spectrographs and spectrometers based on Czerry-Turner and Ebert mountings, thermal detector, photodiode, photomultiplier tube, channel electron multiplier, charge coupled detector, principle and working of a double beam infrared spectrophotometer, Raman spectrometer, principle and working of Fourier transform spectrometers.	10 lectures
UNIT-V	**Relaxation in liquids-theory and experiment:**introduction, Langevin equation, Fokker-Plank equation, Smoluchowski equation, Raman line shape measurement, ultrafast chemical reactions, single molecule spectroscopy, phase relaxation.	8 lectures

Recommended Books:

1. Laser spectroscopy: Basic Concepts and Instrumentation, W. Demtroder, 3rd Edition (Springer)
2. Principles of Lasers, O. Svelto, 4th Edition (Plenum Press)
3. Laser Cooling and Trapping, P. N. Ghosh
4. Molecular Relaxation in Liquids, B. Bagchi (Oxford University Press)

PH9003: Group Theory, Spectroscopy and Diffraction Method

(Pre-PhD course work optional paper) **3 0 0 3**

UNIT-I	**Symmetry:**Group, symmetry elements, symmetry operations and their matrix representations, point groups and character tables.	10 lectures
UNIT-II	**Vibrational spectroscopy and character tables:** normal modes of vibrations, infrared and Raman spectroscopy, selections rules.	6 lectures
(**UNIT-III**	**Molecular orbital theory and character tables:** molecular orbital theory background, polyatomic molecules, transition metal complexes and ligand field splitting.	8 lectures
UNIT-IV	**Electronic spectroscopy:** interpretation, group theory applications and transition moment integral, hot bands.	6 lectures
UNIT-V	**Crystallography and groups:** crystallographic space groups, crystallographic point groups, point group theorem, crystallographic restriction theorem.	6 lectures
UNIT-VI	**Crystallography and diffraction:** diffraction techniques, X-ray diffraction patterns, indexing pattern, data collection and data analysis.	6 lectures

Recommended Books:

1. Symmetry and Spectroscopy, D.C. Harris and M.D. Bertolucci (Dover)
2. Chemical Applications of Group Theory, 3rd Edition, F.A. Cotton (Wiley-Blackwell)
3. Introduction to Crystallography, D.E. Sands (Dover)
4. X-ray Strucure Determination: A Practical Guide, G. H. Stout and L.H. Jensen (Wiley)

PH9004: Luminescent Materials and Their Applications

(Pre-PhD course work optional paper) **3 0 0 3**

UNIT-I	**General Aspects:** Luminescence and its simple explanation, difference between thermal and luminescence emission, positive, negative, secondary and non-radiative luminescence, rate and duration of luminescence, Stoke's rules and luminescence yield.	8 lectures
UNIT-II	**Types of luminescence:** classification of luminescence on the basis of (i) time dependence of emission: phosphorescence and fluorescence (ii) nature of exciting energy source: photoluminescence, cathodoluminescence and thermoluminescence.	8 lectures
UNIT-III	**Theory of luminescence:** band theory and configuration coordinate models, Randal and William's theory for derivation of the phosphorescence and thermoluminescence intensity equations.	7 lectures
UNIT-IV	**Lumiscent materials:** explanation of terms-activator, self activator, role of impurity in luminescent materials and preparation of pure and impurity activated materials in amorphous, crystalline and pellet forms. Instrumentation and techniques involved in measurement of luminescent, recording of fluorescence, phosphorescence and thermoluminescence emission.	11 lectures
UNIT-V	**Physical and chemical effects on luminescence:** effects of thermal, mechanical, impurity, radiation aspects of luminescence, applications of luminescence in various fields.	8 lectures

Recommended Books:

1. Luminescence in Crystals (translated), E.G. Garlie (Wiley)
2. Theory of Luminescence, B.F. Steponov and V.P. Gribkovskii (Springer)
3. Luminescence of Inorganic Solids, P. Goldberg (Academic Press)
4. National Symposium on TL and its application – Published report BARC 1975.

PH9005: Lie Algebraic Techniques in Physics

(Pre-PhD course work optional paper) **3 0 0 3**

UNIT-I	**Lie algebras:** basic concepts, Lie superalgebras, direct sum, ideals, semi-simple Lie algebras, semi-direct sum, Killing form, compact and noncompact algebras, derivations, nilpotent algebras, invariant operators, structure of Lie algebras, Cartan-Weyl form, root vectors, Dynkin diagrams, isomorphism, enveloping algebras.	10 lectures
UNIT-II	**Irreducible representations:** abstract characterization, irreducible tensors, contractions, tensor representations, fundamental representations of unitary algebras, isomorphisms of spinor algebras, dimensions of representations, action of Lie algebra, tensor products, non-canonical chains.	10 lectures
UNIT-III	**Casimir and tensor operators:** Casimir operators of Lie algebras and extended Lie algebras, complete set of commuting operators, eigenvalues of Casimir operators, coupling and recoupling coefficients, Wigner-Eckart theorem, nested algebras, Racah's factorization lemmas, adjoint operators, coupled tensor operators, reduction formula.	12 lectures
UNIT-IV	**Realizations of Lie algebras:** boson realization, fermion realization, differential realization, matrix realization, spectrum generating algebras, dynamic symmetries, degeneracy algebras, dynamical algebras.	10 lectures

Recommended Books:

1. Lie Algebras and Applications, F. Iachello (Springer)
2. Lie Algebras, N. Jacobson (Dover)
3. Lie Groups and Lie Algebras, A. Das and S. Okubo (Hindustan Books)
4. Algebraic Theory of Molecules, F. Iachello and R.D. Levine (Oxford University Press)

PH9006: Climate Physics

(pre-PhD course work optional paper) **3 0 0 3**

UNIT-I	**Radiative transfer:** spectra of short and long wave radiations, description of radiative transfer, equation of radiative transfer, absorption characteristics of gases, radiative transfer in a plane parallel atmosphere, thermal equilibrium, thermal relaxation, greenhouse effect.	8 lectures
UNIT-II	**Aerosols and clouds:** aerosol morphology, microphysics and macrophysics of clouds, radiative transfer in aerosols and clouds, roles of clouds and aerosols in climate.	8 lectures
UNIT-III	**Atmospheric motion:** geostrophic equilibrium, vertical shear of geostrophic wind, frictional geostrophic motion, curvilinear motion, weakly divergent motion.	8 lectures
UNIT-IV	**Wave propagation:** description of wave propagation, acoustic waves, buoyancy waves, Lamb wave, Rossby wave, wave absorption, nonlinear consideration.	8 lectures
UNIT-V	**General circulation:** forms of atmospheric energy, heat transfer in a zonally symmetric circulation, heat transfer in a laboratory analogue, quasi-permanent features, fluctuations of the circulation.	8 lectures
UNIT-VI	**Influence of ocean:** composition and structure, role in heat budget, role in carbon cycle, wind driven circulation, buoyancy driven circulation, inter-annual changes.	6 lectures

Recommended Books:

1. Physics of Atmoshere and Climate, M.L. Salby, 2nd Edition (Cambridge University Press)
2. An Introduction to Atmospheric Thermodynamics, A. A. Tsonis, 2 nd Edition(Cambridge University Press)
3. Elementary Climate Physics, F.W. Taylor (Oxford University Press)
4. Fundamentals ofAtmospheric Physics, M. L. Salby, Vol. 61 (International Geophysics), Ist Ed., academic Press, 1996.

PH 9007: Plasma Physics

(pre-PhD course work optional paper) **3 0 0 3**

UNIT-I	**Introduction:** Plasma-definition, Concept of Plasma Temperature, Debye shielding, plasma frequency, motion of charged particle in electromagnetic field, parallel acceleration and magnetic mirror effect, plasma applications.	10 lectures
UNIT-II	**Plasma as a fluid:** Fluid equation of motion, fluid drifts, plasma approximation, Plasma oscillations, Electron and ion plasma waves- their dispersion relations and properties, electromagnetic waves in plasma, Hydromagnetic waves, plasma diffusion and resistivity, single fluid MHD equation, concept of plasma E, plasma instability: two-stream instability, Rayleigh-Taylor instability.	12 lectures
UNIT-III	**Kinetic theory of plasma and its application:** Velocity Distribution function, Vlasov equationand Folker –Plank equation, Landau damping, BGK modes.	6 lectures
UNIT-IV	**Nonlinear Effects in plasma:** Nonlinear phenomena in plasma, Linear and non-linear waves in plasma , Introduction to Reductive Perturbation Method of Nonlinear Plasma Wave, concept of Pseudo Potential (Sagdeev Potential), Theory of Plasma Sheath and its relation to Nonlinear Waves (Soliton). Bohm sheath criteria and Mech number.	8 lectures
UNIT-V	**Plasma in controlled thermonuclear rector:** Introduction to controlled thermonuclear fusion, magnetic confinement; Tokamak, ITER.	4 lectures
UNIT-VI	**Plasma Simulation:** Fluid simulation and kinetic simulation, Basics of PIC, Vlasov and MD simulation.	2 lectures

Recommended Books:

1. Francis F Chen; Introduction to plasma physics and controlled fusion vol. I.
2. K. Nishikawa; Plasma physics basic theory with fusion applications.
3. J. A. Bittencourt; Fundamentals of plasma physics.

PH-9008: MODERN APPLICATIONS OF SPECTROSCOPY

(pre-PhD course work optional paper) **3 0 0 3**

UNIT-I	**GROUP THEORY AND ITS APPLICATION TO SPECTROSCOPY :** Symmetry elements, symmetry operations and groups, Molecular point groups, Character table for point groups, Selection Rules, Properties of Irreducible representation, Polarised, Raman spectra , IR and Raman activity.	8 lectures
UNIT 2 :	**ANALYSIS OF MOLECULAR VIBRATIONS :** Molecular vibrations, Normal modes of vibrations, Vibrational energy, Force field, Different types of force fields, Force constants, Secular equations, Evaluation of force constants, important molecular constants and theirdetermination.	8 lectures
UNIT 3 :	**ULTRAVIOLET - SPECTROSCOPY :** UV and visible spectroscopy, Transition of organic molecules, Colour and light absorption, theory of electronic spectroscopy , Bathochromic effect , Instrumentation and sampling, Choice of solvent, Applications , Qualitative and Quantitative Analysis.	8 lectures
UNIT 4 :	**IR AND RAMAN SPECTROSCOPY :** Theory of IR spectroscopy , IR spectrometers , Sample Handling Techniques ,Applications of IR Spectroscopy. Raman activity , Use of Lasers in spectroscopy, Theory, Raman intensities and bondpolarizability , Applications to organic, Inorganic and Physical chemistry.	9 lectures
UNIT 5 :	**APPLICATIONS OF SPECTROSCOPY :** Recording and analysis of IR and Raman spectra of complicated molecules, groupfrequencies , intensities of Raman and IR bands, structure determination , Pharmaceuticalapplications ,biosensors-SERS-TERS, Raman in nanomaterials and biomolecules.	9 lectures

Recommended Books:

1. Raman, K.V. 1998. Group theory and its applications to Chemistry. Tata McGraw Hill Co., New Delhi.
2. Colthup, N.B., Daly, L.V. and Wiberly, 1975. Introduction to IR and RamanSpectroscopy. Academic Pres s, New York.
3. Silverstein Bassler and Morrill 1900. Spectroscopic Identification of OrganicCompounds. John-Wiley.
4. A. Tiwari, Anthony P. F. Turner , 2014 , Biosensors Nanotechnology, S. publishing LLC & **Wiley.**

PH 9009: Microwave Electronics and Antenna Theory

(pre-PhD course work optional paper) **3 0 0 3**

UNIT-I	Transmission lines, smith chart, waveguides, rectangular cavity, modes in waveguides and cavities, dielectric filled wave guides, dielectric slab guide, modal expansion of fields and its applications.	8 lectures
UNIT II:	Microwave transistor, microwave tunnel diode, varactor diode, Schottky diode, Microwave generation and amplification, avalanche effect devices: Gunn diode, klystron, reflex klystron: power output and efficiency; traveling wave tubes, magnetron.	6 lectures
UNIT III:	Attenuators, phase shifters, matched loads, detectors and mounts, slotted-sections, E-plane tee, H-plane tee, hybrid tees, directional couplers, tuners, circulators and isolators. Signal generators: fixed frequency, sweep frequency and synthesized frequency oscillators; frequency meters, VSWR meters, measurements of frequency, attenuation, VSWR and impedance.	8 lectures
UNIT IV:	Dipole, monopole, microstrip, wire, loop and helix antennas, aperture antenna-slot, waveguide and horn antenna; parabolic reflector antenna. Antenna characteristics: radiation patterns, directive gain, side lobe, back lobe, polarization, co-polarization and cross polarization level, frequency range, beam width, input impedance, bandwidth, efficiency. Microstrip antenna: Different substrate materials, rectangular and circular patch, feed for microstrip antennas: probe feed, microstrip line feed, aperture feed, electromagnetically fed microstrip patch.	14 lectures
UNIT V:	Microwave integrated circuits: different planar transmission lines, characteristics of microwave integrated circuits.	6 lectures

Recommended Books:

1. Rizzi, P.A., Microwave Engineering, (Prentice-Hall, 1999)
2. Griffiths, D. J., Introduction to Electrodynamics, (Prentice-Hall, 2009)
3. Jackson, J. D., Classical Electrodynamics, 3rd edition, (John Wiley & Sons, 1998)
4. Pozar, D. M., Microwave Engineering, 3rd edition(Wiley India Pvt. Ltd, 2009)
5. Liao, S. Y., Microwave Devices and Circuits, 3rd edition(Princeton Hall, 2000)
6. Collin, R. E, Foundations for Microwave Engineering, (McGraw-Hill, 1992)